REPORT DOCUMENTATION PAGE

Form Approved OMB NO. 0704-0188

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
30-07-2014	Final Report	1-Oct-2013 - 30-Jun-2014

4. TITLE AND SUBTITLE
Final Report: STIR: Assessing and Training Response Inhibition Abilities

5a. CONTRACT NUMBER
W911NF-13-1-0480

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
611102

6. AUTHORS
Adam T. Biggs, Stephen R. Mitroff

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAMES AND ADDRESSES
Duke University
2200 W Main St Ste 710

Durham, NC 27705 -4677

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS (ES)
U.S. Army Research Office
P.O. Box 12211
Research Triangle Park, NC 27709-2211

10. SPONSOR/MONITOR'S ACRONYM(S)
ARO

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
64423-LS-II.1

12. DISTRIBUTION AVAILIBILITY STATEMENT
Approved for Public Release; Distribution Unlimited

13. SUPPLEMENTARY NOTES
The views, opinions and/or findings contained in this report are those of the author(s) and should not contrued as an official Department of the Army position, policy or decision, unless so designated by other documentation.

14. ABSTRACT
Shooting a firearm involves a complex series of actions, and each action depends on a distinct cognitive process (e. g., finding targets involves visual search, aiming involves perceptual judgments of distance and motion). Examining these action-cognition links provides a valuable tool for revealing how cognitive mechanisms interact with one another in addition to offering new avenues for enhancing shooting performance and safety. The present study established a direct relationship between a critical shooting error, civilian casualties, and a particular cognitive ability, response inhibition. Response inhibition abilities significantly correlated with civilian casualties

15. SUBJECT TERMS
Civilian casualties, response inhibition, cognitive training

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	15. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Adam T. Biggs
UU	UU	UU	UU		19b. TELEPHONE NUMBER: 919-668-6144

Report Title

Final Report: STIR: Assessing and Training Response Inhibition Abilities

ABSTRACT

Shooting a firearm involves a complex series of actions, and each action depends on a distinct cognitive process (e.g., finding targets involves visual search, aiming involves perceptual judgments of distance and motion). Examining these action-cognition links provides a valuable tool for revealing how cognitive mechanisms interact with one another in addition to offering new avenues for enhancing shooting performance and safety. The present study established a direct relationship between a critical shooting error, civilian casualties, and a particular cognitive ability, response inhibition. Response inhibition abilities significantly correlated with civilian casualties in a shooting simulation, and response inhibition training—but not a control form of cognition training—reduced civilian casualties. Survey and behavioral measures revealed that civilian casualties were not related to motor impulsivity (i.e., an itchy trigger finger), but rather to an individual's ability to withhold an initiated response (i.e., an itchy brain). This study demonstrated successful response inhibition training and "far transfer"1,2 learning, where individuals improved on a task only conceptually related to the training. Likewise, the study demonstrated the rich potential of developing specific forms of cognitive training to improve shooting performance for military and law enforcement personnel.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received Paper

TOTAL:

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received Paper

TOTAL:

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received Paper

TOTAL:

Number of Manuscripts:

Books

Received Book

TOTAL:

Received	Book Chapter

TOTAL:

Patents Submitted

Patents Awarded

Awards

Graduate Students

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

NAME	PERCENT_SUPPORTED	National Academy Member
Stephen Mitroff	0.00	
FTE Equivalent:	**0.00**	
Total Number:	**1**	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period:	0.00
The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:	0.00
The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:	0.00
Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):	0.00
Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:	0.00
The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense	0.00
The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:	0.00

Names of Personnel receiving masters degrees

NAME
Total Number:

Names of personnel receiving PHDs

NAME
Total Number:

Names of other research staff

NAME	PERCENT_SUPPORTED
Adam Biggs	1.00
FTE Equivalent:	**1.00**
Total Number:	**1**

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

Technology Transfer

(1) Foreword (optional): not provided

(2) Table of Contents (if report is more than 10 pages): less than 10 pages

(3) List of Appendixes, Illustrations, and Tables (if applicable):

(4) Statement of the problem studied:

Shooting a firearm involves a complex series of actions, and each action depends on a distinct cognitive process (e.g., finding targets involves visual search, aiming involves perceptual judgments of distance and motion). Examining these action-cognition links provides a valuable tool for revealing how cognitive mechanisms interact with one another in addition to offering new avenues for enhancing shooting performance and safety. The present study established a direct relationship between a critical shooting error, civilian casualties, and a particular cognitive ability, response inhibition. Response inhibition abilities significantly correlated with civilian casualties in a shooting simulation, and response inhibition training—but not a control form of cognition training—reduced civilian casualties. Survey and behavioral measures revealed that civilian casualties were not related to motor impulsivity (i.e., an itchy trigger finger), but rather to an individual's ability to withhold an initiated response (i.e., an itchy brain). This study demonstrated successful response inhibition training and "far transfer"[1,2] learning, where individuals improved on a task only conceptually related to the training. Likewise, the study demonstrated the rich potential of developing specific forms of cognitive training to improve shooting performance for military and law enforcement personnel.

(5) Summary of the most important results:

The act of shooting a firearm involves an impressively complex cascade of actions, and each action can be linked to a specific cognitive ability. For example, finding appropriate targets involves visual search, determining whether someone is friend or foe involves decision-making processes, taking aim involves perceptual estimations of distance and motion, and pulling the trigger (or withholding the shot) involves response execution (or inhibition). Given this intricate series of cognitive functions, shooting behaviors provide an excellent opportunity to examine the links between action and cognition.

There are two primary research endeavors that can be informed by examining the action-cognition links of the shooting process. First, much can be gleaned about how individual cognitive mechanisms interact if studied through the preceding and following processes involved in shooting behaviors. This point is especially relevant when considering that successful shooting behaviors require success at each step of the cognitive process. Second, these action-cognition links can be leveraged to inform cognitive training methods. Training effects can broadly take

two forms: (1) "near transfer"—when two situations are highly similar in context and execution, or (2) "far transfer"— when two situations are only conceptually similar. Near transfer would be, for example, learning a song on one piano and then playing it on another piano, and far transfer would be replaying the song on a guitar instead of a piano. Far transfer requires an abstract application of the core learning principle[1,2], and viable examples are often hard to find and/or assess. If exposure to non-shooting activities can improve shooting performance, this would offer a prime example of far transfer.

The current study focused on one specific relationship between shooting performance and cognition—civilian casualties and response inhibition. Civilian casualties occur when a shooter hits a non-combatant with weapons fire[3,4]. These incidents can have dramatic psychological, economical, and practical implications, and therefore every effort should be made to minimize their occurrences. The current project looks to understand and reduce civilian casualties by studying them in relation to the cognitive ability of response inhibition—the ability to stop from performing an already initiated behavior[5-9]. Most everyone has experienced successful and failed response inhibition; take for instance when you start the motion to hit the "send" button on an email, and then you suddenly realize that it is addressed to the wrong person. Sometimes you successfully abort the button-press behavior (i.e., successful response inhibition), but sometimes you do not (i.e., failed response inhibition). Initiated responses can be successfully withheld, even with very brief time windows between the decision to respond and the response inhibition signal[10-12], yet this can be cognitively challenging. When applying the logic of response inhibition to the act of shooting a firearm, consider the situation where a shooter takes aim at a target and initiates the process to fire the weapon—but then realizes that the target is a civilian. The shooter must rely upon response inhibition skills to successfully inhibit a trigger pull upon identifying the person as a non-target.

Exploring this particular relationship between shooting and cognition—and others like it—can also offer highly practical benefits. First, the action-cognition links between shooting and cognitive abilities would help identify those individuals best suited for performing specific shooting tasks—or conversely, individuals who are most likely to make particular types of errors. For example, if the proposed relationship between civilian casualties and response inhibition is established, the individuals most likely to inflict civilian casualties could be identified before being sent into combat. Second, if specific cognitive abilities can predict specific aspects of shooting performance, then individualized training could be developed to help a particular person avoid an error to which he or she is predisposed. Civilian casualties could then be reduced if shooters underwent the appropriate cognitive training. These combined efforts could have substantial potential for military and law enforcement efforts in performance, training, and evaluation. Such new training methods are particularly important in light of recent evidence that deliberate practice alone may not be as influential for performance in professional tasks as once believed[13].

The present study included three components: a large baseline cohort of participants to establish potential relationships between attentional abilities and civilian casualties, a response inhibition training (RIT) group to assess the efficacy of training, and an active control training group (visual search training; VST) to eliminate methodological concerns involving placebo effects[14,15]. Baseline measurements included shooting performance, cognitive abilities, and self-report surveys to examine whether civilian casualties were related to individual differences in response inhibition, attentional deficits, or impulsivity. The key dependent variable was civilian casualties within a simulated shooting environment[16] containing a mix of both intended targets

(i.e., hostiles) and unintended targets (i.e., civilians). Training participants completed a 5-day training protocol either designed to reduce civilian casualties (RIT) or designed to enhance a cognitive ability conceptually unrelated to civilian casualties (VST).

Baseline Differences. Performance on a Stop Signal Reaction Time (SSRT) task, which measured an individual's ability to withhold an initiated response, was significantly related to the number of civilian casualties at baseline ($r(85)=.26$, $p<.05$) with poorer performance on the SSRT task related to increased civilian casualties. Two attention-related self-report scales were significantly related to the number of civilian casualties at baseline: increased civilian casualties were related to higher ADHD score[17], $r(84)=.21$, $p<.05$, and greater attentional impulsivity[18,19], $r(82)=.24$, $p<.05$. Civilian casualties were not related to self-reported motor impulsivity[18,19], $r(83)=.12$, $p=.27$, nor the total number of shots fired in the simulated shooting task[16]—a behavioral measure of motor impulsivity, $r(86)=.08$, $p=.44$.

Training Effects. Civilian casualties were significantly reduced from pre-test to post-test for the RIT group, but not for the VST group, $F(1,55)=4.10$, $p<.05$, $\eta_p^2=.07$ (Figure 1). This reduction could not be explained by a group difference in civilian casualties at pre-test, $t(55)=0.69$, $p=.49$, nor by a reduction in the number of intended targets hit as RIT participants improved more than VST participants in intended targets performance, $F(1,55)=4.10$, $p<.05$, $\eta_p^2=.07$. RIT participants also improved their ability to inhibit an initiated response on the SSRT task from pre-test to post-test ($t(27)=2.25$, $p<.05$), whereas the VST group showed no change ($t(27) = 0.92$, $p = .36$). Finally, increased self-reported ADHD symptoms[17] were associated with a larger reduction in civilian casualties from pre-test to post-test for the RIT group, but not the VST group (Figure 2).

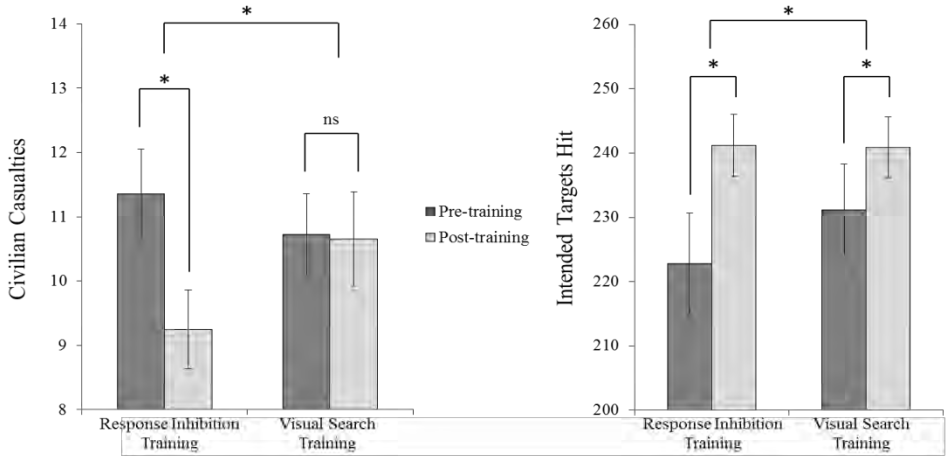

Figure 1. Shooting performance at pre-test and post-test for each training condition for civilian casualties (left graph) and intended targets hit (right graph). Dark gray bars represent pre-test scores and light gray bars indicate post-test scores.

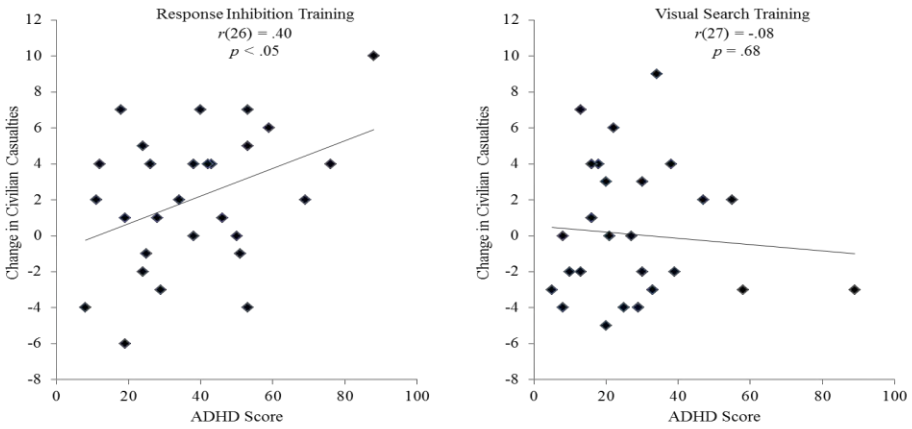

Figure 2. Change in civilian casualties (pre-test minus post-test) as compared to an individual's ADHD score on the Jasper-Goldberg Adult ADD/ADHD Questionnaire separated by training condition. Larger ADHD score represents increased self-reported symptoms associated with ADHD.

Conclusions. The current study revealed important links between civilian casualties in a simulated shooting environment and the cognitive ability of response inhibition. First, individuals with poor inhibitory control and high attentional impulsivity were more likely to inflict civilian casualties during the shooting scenarios. Second, a lack of a relationship between civilian casualties and motor impulsivity highlights the cognitive underpinning—an itchy brain caused civilian casualties more so than an itchy trigger finger. Finally, civilian casualties were significantly reduced via response inhibition training (compared to a conceptually unrelated cognitive training group), and individuals who self-reported high levels of ADHD symptoms benefited most from the training. This latter point indicates that not only do some people benefit more from training than others, but also that such individuals could be identified prior to training.

From an academic perspective, the training results are a prime demonstration of "far transfer" in cognitive learning[1,2]. RIT sessions involved computer-based SSRT and go/no-go tasks that were clearly different from the shooting scenarios, yet RIT participants significantly improved on their ability to avoid shooting civilians. In contrast to previous results[20,21], the current findings offer exciting evidence of generalized response inhibition training that expands upon previous successful "near transfer" response inhibition training efforts—such as treating alcohol addictions by enhancing inhibitory signals for alcohol-specific stimuli[22,23].

Practically, the current study provides promise for improving shooting performance for a range of individuals, including military and law enforcement personnel. The relationship between response inhibition abilities and civilian casualties provides a means of identifying those individuals most likely to inflict civilian casualties. Furthermore, successful training efforts could reduce the likelihood of these casualties occurring in the field. Similar efforts can yield further targeted training regimens so that the most effective training can be implemented for any given scenario; for example, some shooters (e.g., competitive sports shooters) might want to specifically enhance their ability to pick up potential targets through visual search, whereas other shooters (e.g., military and law enforcement personnel) might want to specifically enhance their ability to avoid hitting unintended targets—thereby reducing civilian casualties or friendly fire incidents[24].

(6) Bibliography

1. Barnett, S.M., & Ceci, S.J. (2002). When and where do we apply what we learn?: A taxonomy for far transfer. *Psychological Bulletin*, *128*, 612-637.
2. Karbach, J., & Kray, J. (2009). How useful is executive control training? Age differences in near and far transfer of task-switching training. *Developmental Science*, *12*, 978-990.
3. Wright, R.G. (2003). Combating civilian casualties: rules and balancing in the developing law of war. *Wake Forest Law Review*, *38*, 129-172.
4. Kahl, C.H. (2007). In the crossfire or the crosshairs? Norms, civilian casualties, and US conduct in Iraq. *International Security*, *32*, 7-46.
5. Verbruggen, F., & Logan, G.D. (2008). Response inhibition in the stop-signal paradigm. *Trends in Cognitive Sciences*, *12*, 418-424.
6. Menon, V., Adleman, N.E., White, C.D., Glover, G.H., & Reiss, A.L. (2001). Error-related brain activation during a Go/NoGo response inhibition task. *Human Brain Mapping*, *12*, 131-143.
7. Eagle, D.M., Baunez, C., Hutcheson, D.M., Lehmann, O., Shah, A.P., & Robbins, T.W. (2008). Stop-signal reaction-time task performance: role of prefrontal cortex and subthalamic nucleus. *Cerebral Cortex*, *18*, 178-188.
8. Logan, G.D. (1994). On the ability to inhibit thought and action: A user's guide to the stop signal paradigm. In D. Dagenbach & T. H. Carr (Eds.), *Inhibitory processes in attention, memory, and language* (pp. 189–239). San Diego, CA: Academic Press.
9. Logan, G.D., Schachar, R.J., & Tannock, R. (1997). Impulsivity and inhibitory control. *Psychological Science*, *8*, 60-64.
10. Leotti, L.A., & Wager, T.D. (2010). Motivational influences on response inhibition measures. *Journal of Experimental Psychology: Human Perception and Performance*, *36*, 430-447.
11. Chikazoe, J., Jimura, K., Hirose, S., Yamashita, K.I., Miyashita, Y., & Konishi, S. (2009). Preparation to inhibit a response complements response inhibition during performance of a stop-signal task. *The Journal of Neuroscience*, *29*, 15870-15877.
12. Bissett, P.G., & Logan, G.D. (2011). Balancing cognitive demands: control adjustments in the stop-signal paradigm. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *37*, 392-404.
13. Macnamara, B.N., Hambrick, D.Z., & Oswald, F.L. (2014). Deliberate practice and performance in music, games, sports, education, and professions: A meta-analysis. *Psychological Science.*
14. Boot, W.R., Simons, D.J., Stothart, C., & Stutts, C. (2013). The pervasive problem with placebos in psychology why active control groups are not sufficient to rule out placebo effects. *Perspectives on Psychological Science*, *8*, 445-454.
15. Green, C.S., Strobach, T., & Schubert, T. (2014). On methodological standards in training and transfer experiments. *Psychological research.*
16. Reload: Target Down [Nintendo Wii]. (2013). San Francisco, CA: Mastiff.
17. Jasper, L., & Goldberg, I. (1993). Jasper/Goldberg Adult ADD Questionnaire Retrieved October 1, 2009, from http://www.mentalhelp.net/poc/view_doc.php?id=974&type=doc&cn=ADHD

18. Barratt, E.S. (1959). Anxiety and impulsiveness related to psychomotor efficiency. *Perceptual and Motor Skills, 9*, 191-198.
19. Patton, J. H., Stanford, M. S., & Barratt, E. S. (1995). Factor structure of the Barratt impulsiveness scale. *Journal of Clinical Psychology, 6,* 768-774.
20. Thorell, L.B., Lindqvist, S., Bergman Nutley, S., Bohlin, G., & Klingberg, T. (2009). Training and transfer effects of executive functions in preschool children. *Developmental Science*, *12*, 106-113.
21. Guerrieri, R., Nederkoorn, C., & Jansen, A. (2012). Disinhibition is easier learned than inhibition. The effects of (dis) inhibition training on food intake. *Appetite*, *59*, 96-99.
22. Houben, K., Nederkoorn, C., Wiers, R.W., & Jansen, A. (2011). Resisting temptation: decreasing alcohol-related affect and drinking behavior by training response inhibition. *Drug and Alcohol Dependence*, *116*, 132-136.
23. Houben, K., Havermans, R.C., Nederkoorn, C., & Jansen, A. (2012). Beer à No-Go: Learning to stop responding to alcohol cues reduces alcohol intake via reduced affective associations rather than increased response inhibition. *Addiction*, *107*, 1280-1287.
24. Webb, C.M., & Hewett, K.J. (2010). An analysis of U.S. Army fratricide incidents during the Global War on Terror (11 September 2001 to 31 March 2008). United States Army Aeromedical Research Laboratory - Warfighter Performance and Health Division.

(7) Appendixes

None